TAIWAN

Ulysses (Type IV) Interplanetary Discontinuities and their Consequences

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Type IV discontinuities are those with large field magnitude changes and large field components along the normal. Such discontinuities are found to comprise a significant fraction of all discontinuities detected at high heliographic latitudes. These Type IV and tangential (Type II) discontinuities often bound large field decrease (MD) regions which can affect energetic charged particle trajectories. We determine the statistical properties of the MDs and develop a Monte Carlo model to determine the cross-field diffusion rate of ~MeV protons.

TYPE OF DISCONTINUITY	MASS FLUX ρv_n	CHANGE IN MAGNETIC FIELD $[\vec{H}]$	
ROTATIONAL DISCONTINUITY	$\neq 0$	$[H_t] = 0$	$H_n \neq 0$
TANGENTIAL DISCONTINUITY	0	$[\vec{H}_t] \neq 0$	$H_n = 0$
SHOCK	$\neq 0$	$[\vec{H}_t] \neq 0$ $[H_t] \neq 0$	$H_n \neq 0$
CONTACT DISCONTINUITY	0	$[\vec{H}_t] = 0$	$H_n \neq 0$

Discontinuity Selection Criterion

Tsurutani and Smith (TS) Criterion of Interplanetary Magnetic Field Discontinuity (JGR, 1979):

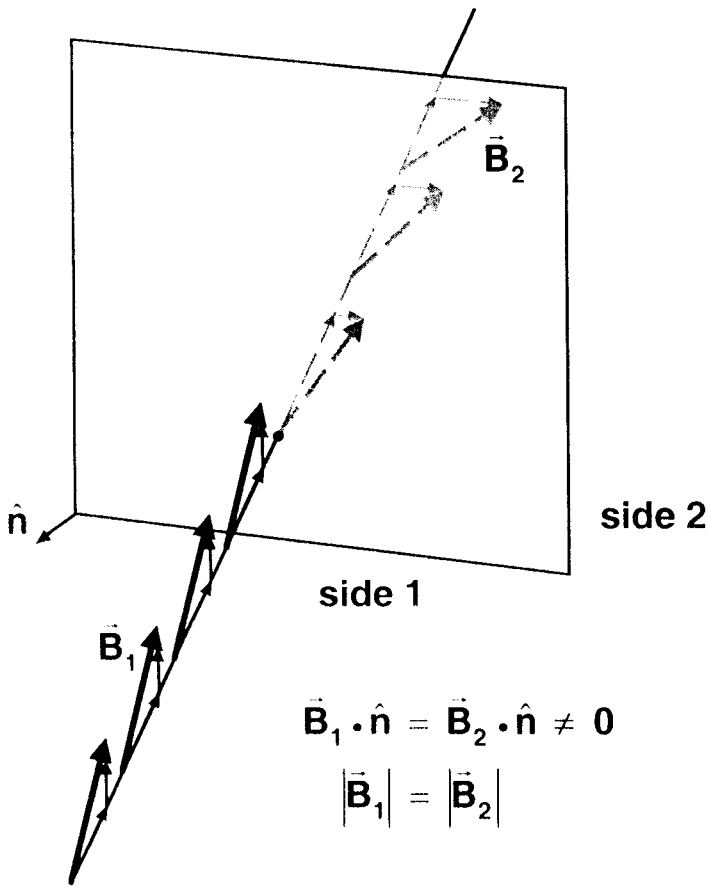
$$\frac{|\Delta B|}{B} \geq 0.5,$$

$$|\Delta B| \geq 2\delta = 2\sqrt{N^{-1}\sum_{i=1}^{N}\left|B_{i+1} - B_i\right|^2}$$

where N=14. Applied to one minute average data, where the two one-minute vectors that are compared are separated by three minutes.

The thickness of discontinuities varies with radial distance. An empirical factor of exp (r-1)/5 has been determined.

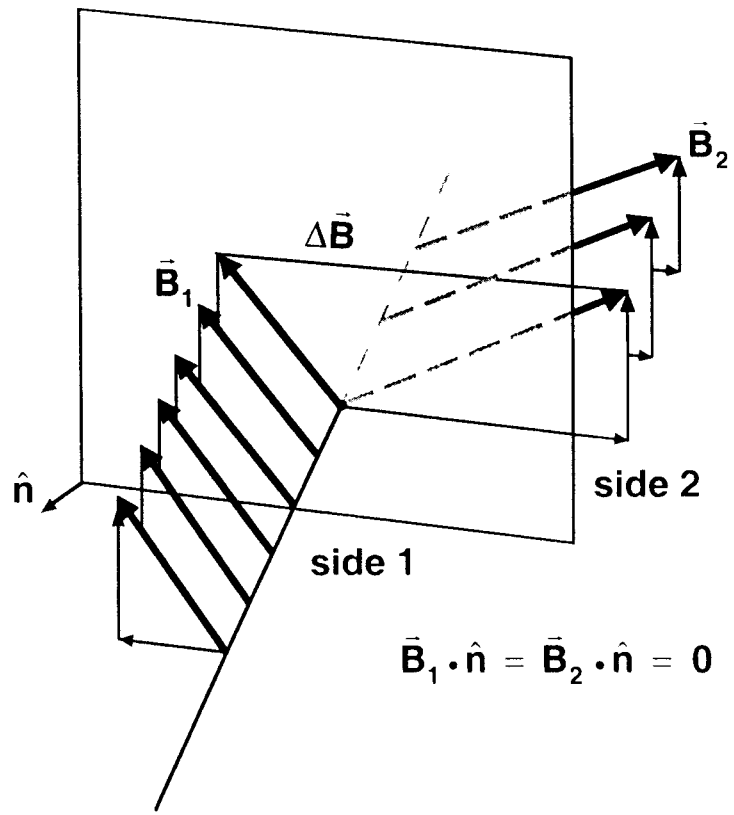
Rotational Discontinuity



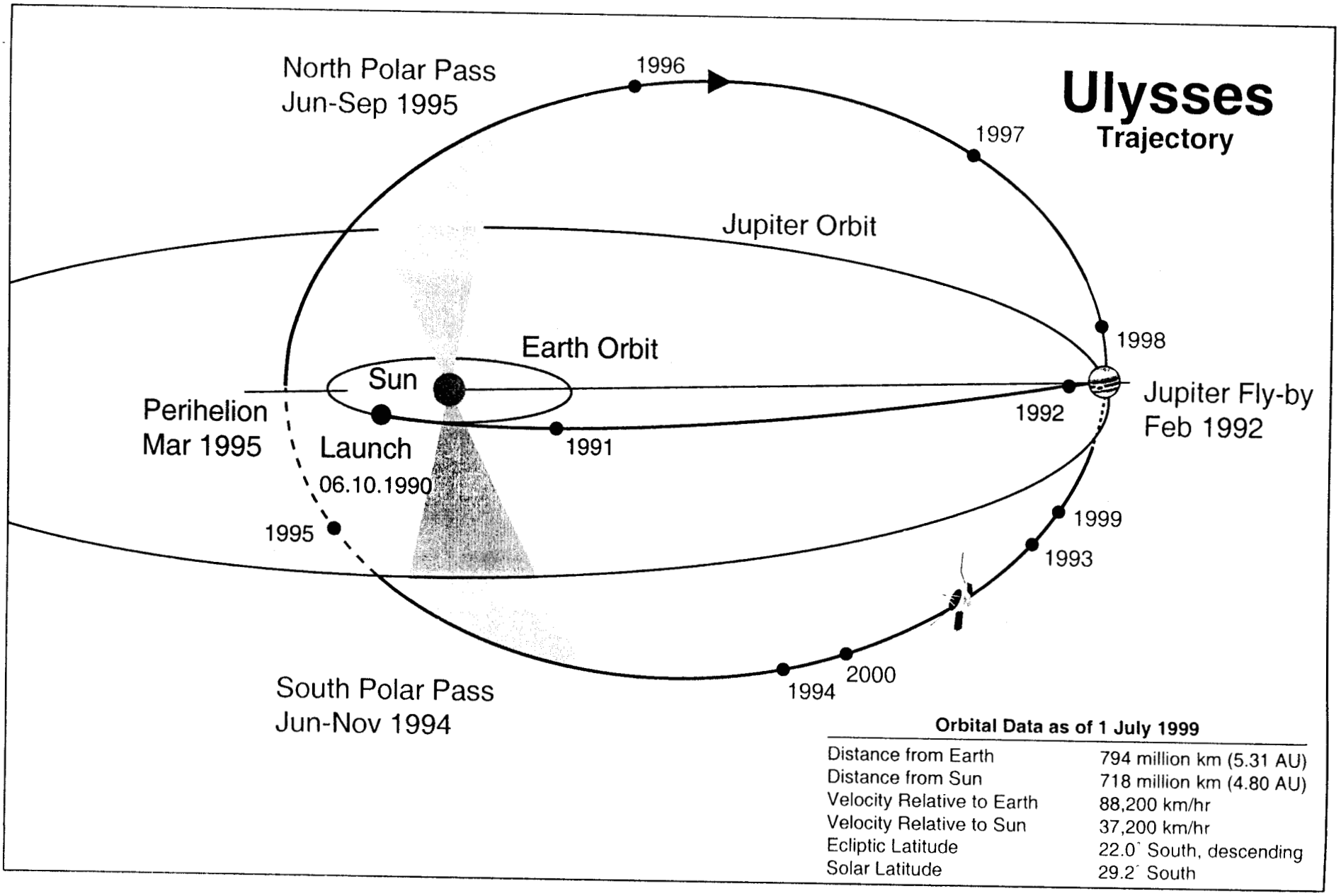
$$\vec{B}_1 \cdot \hat{n} = \vec{B}_2 \cdot \hat{n} \neq 0$$

$$|\vec{B}_1| = |\vec{B}_2|$$

Tangential Discontinuity

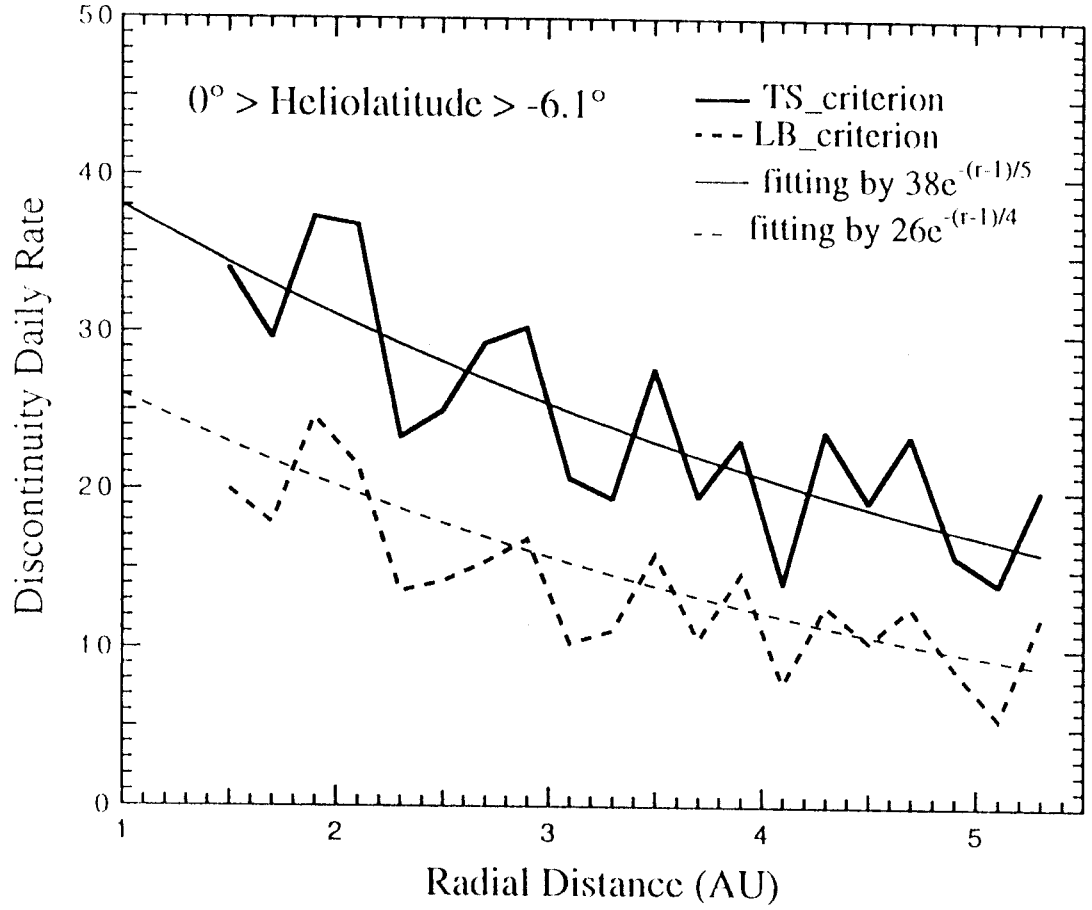


$$\vec{B}_1 \cdot \hat{n} = \vec{B}_2 \cdot \hat{n} = 0$$

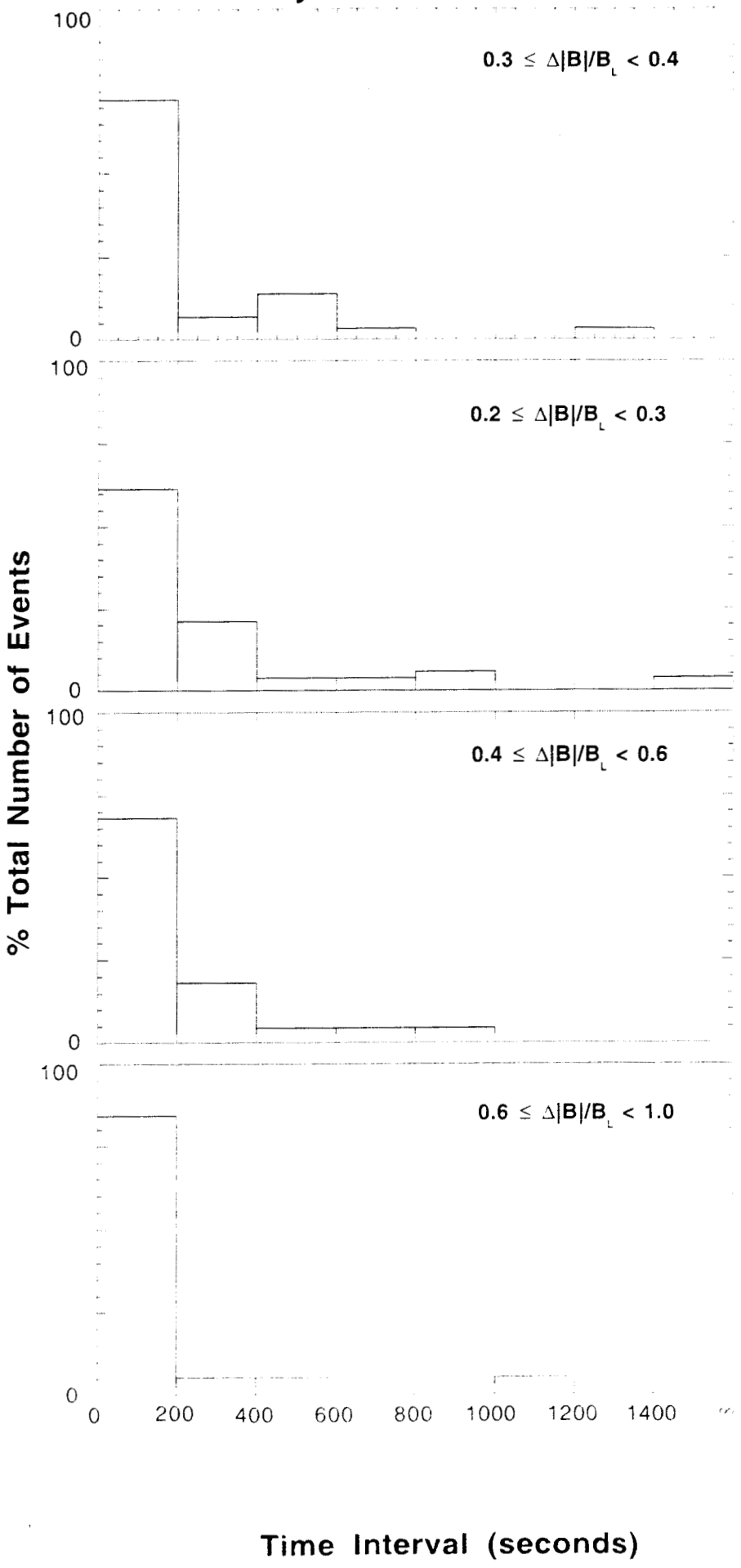


Orbital Data as of 1 July 1999

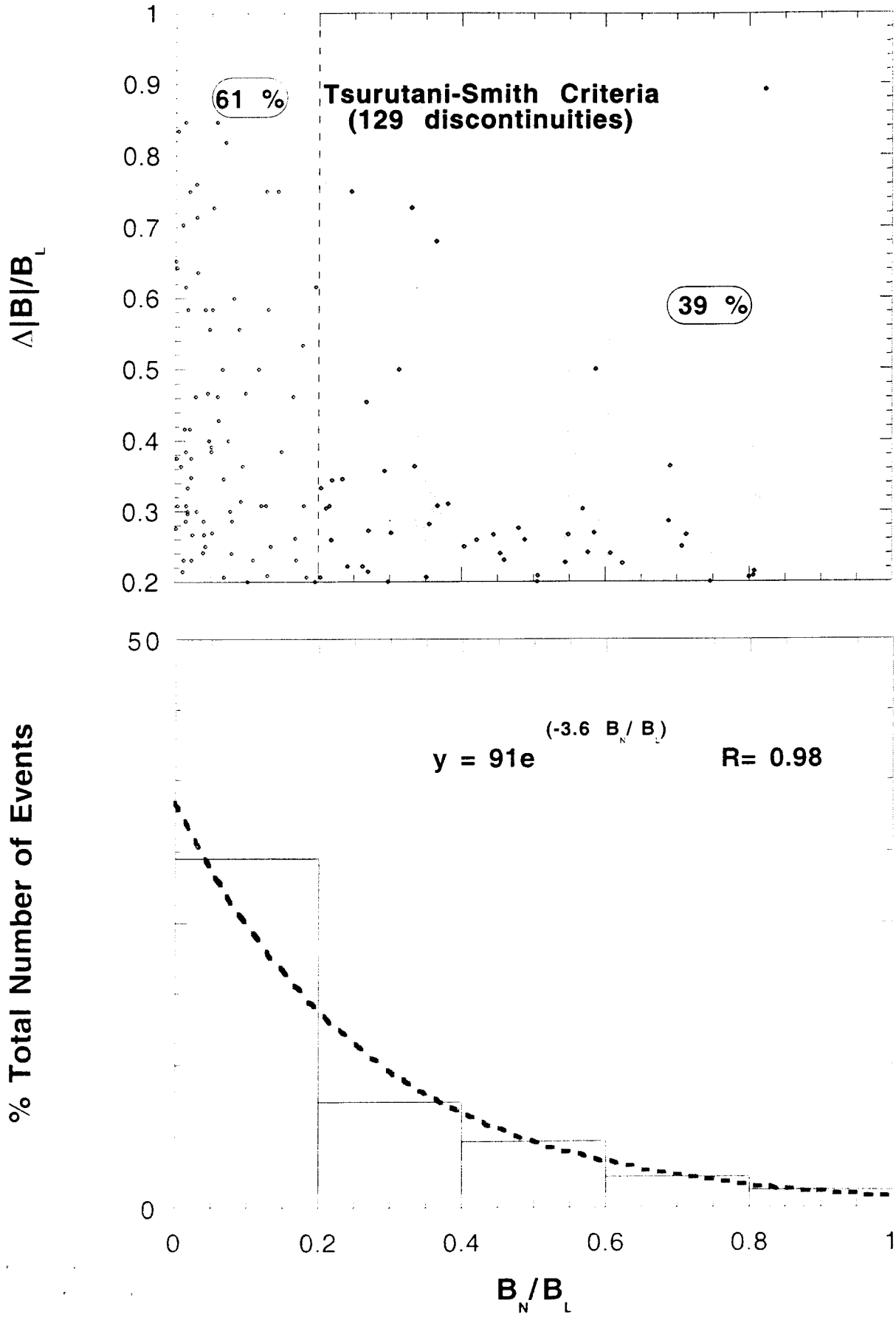
Distance from Earth	794 million km (5.31 AU)
Distance from Sun	718 million km (4.80 AU)
Velocity Relative to Earth	88,200 km/hr
Velocity Relative to Sun	37,200 km/hr
Ecliptic Latitude	22.0˚ South, descending
Solar Latitude	29.2˚ South

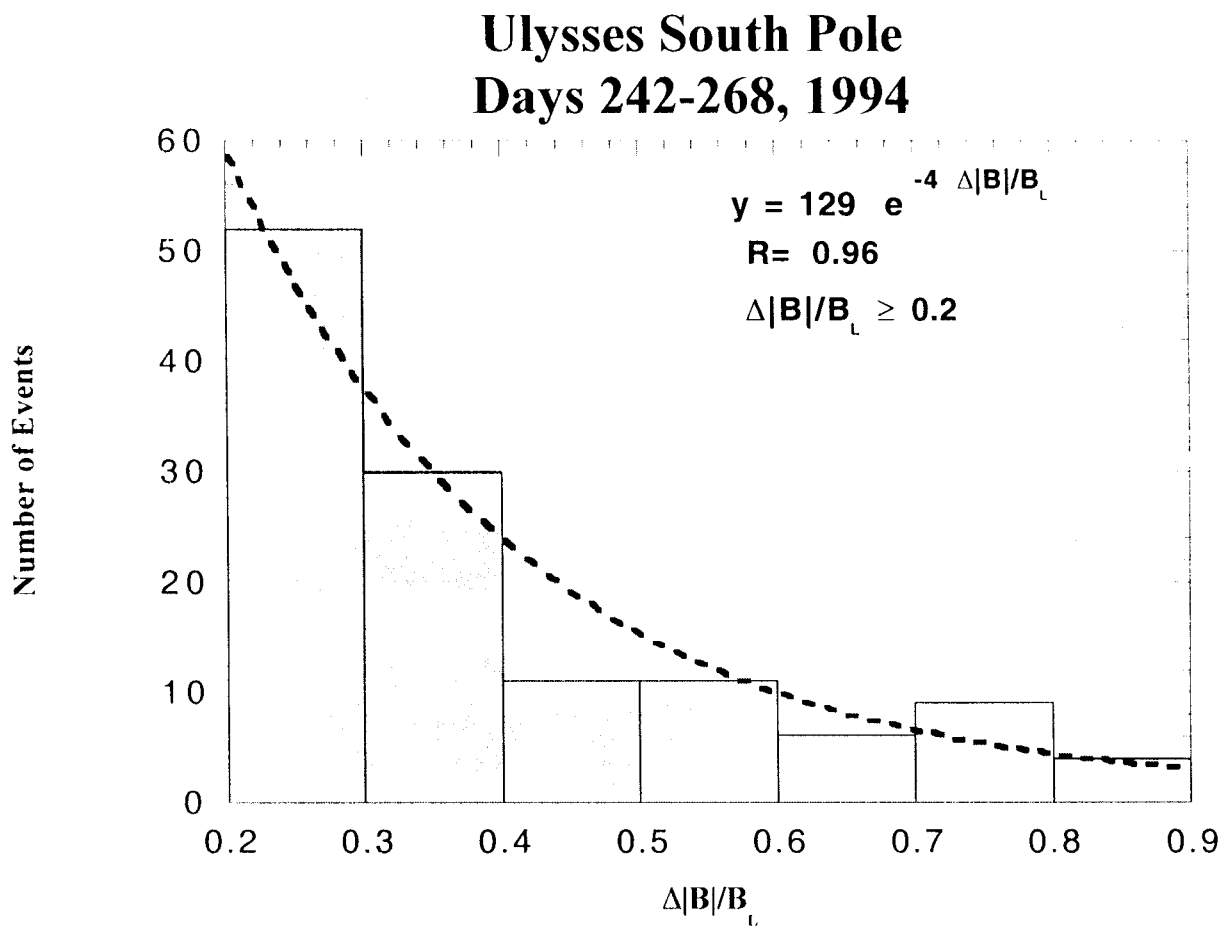

0° > Heliolatitude > -6.1°
TS_criterion
LB_criterion
fitting by 38e^-(r-1)/5
fitting by 26e^-(r-1)/4
Discontinuity Daily Rate
Radial Distance (AU)
0
10
20
30
40
50
1
2
3
4
5

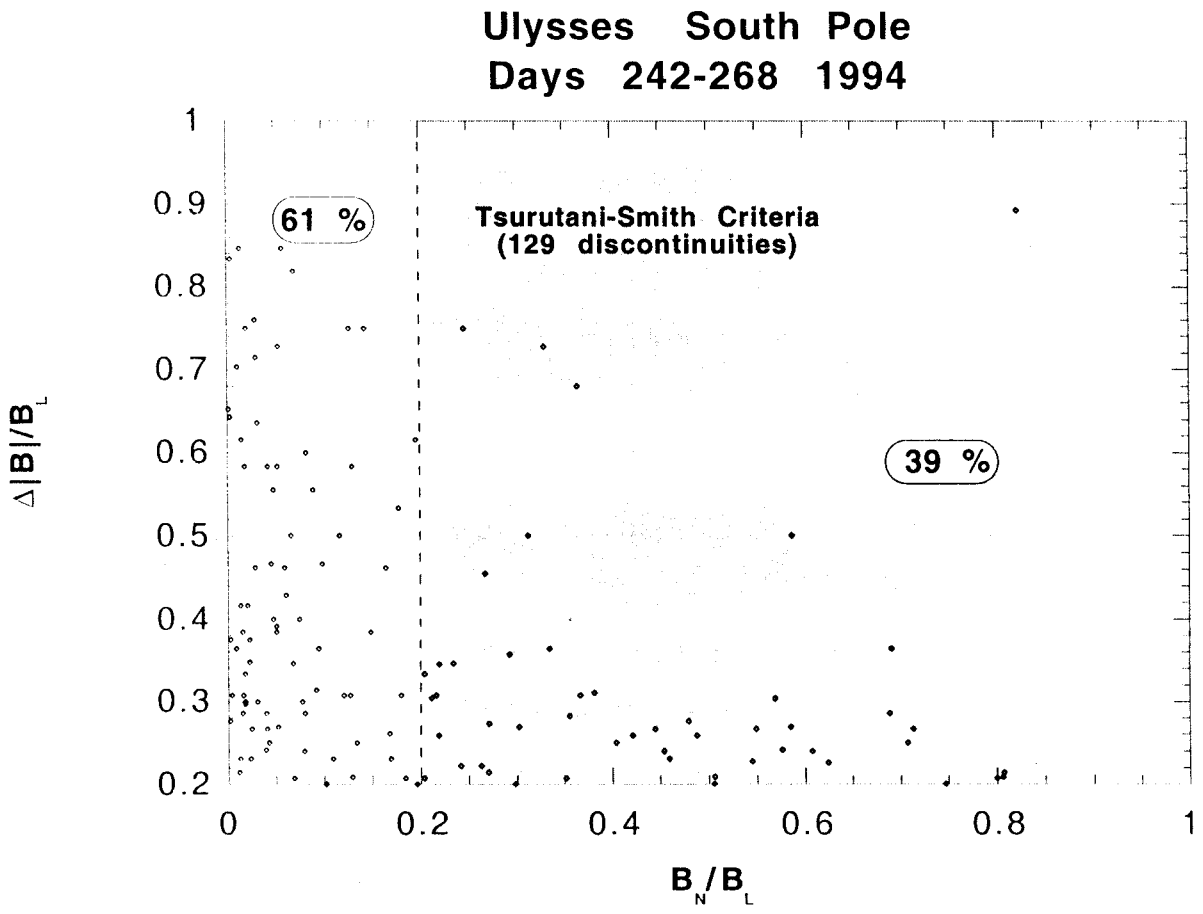
Ulysses South Pole
Days 242-268, 1994

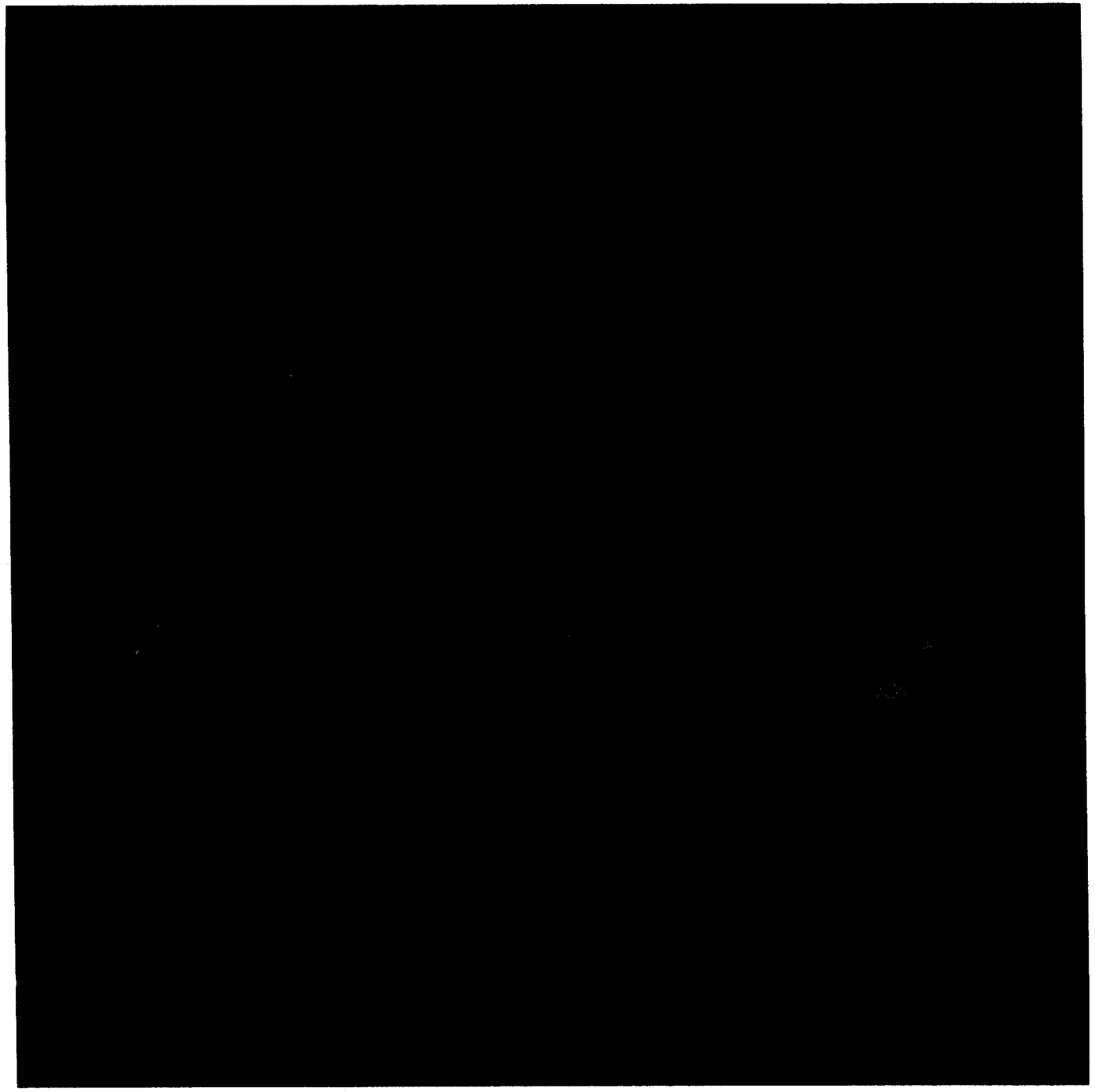


Ulysses South Pole
Days 242-268 1994

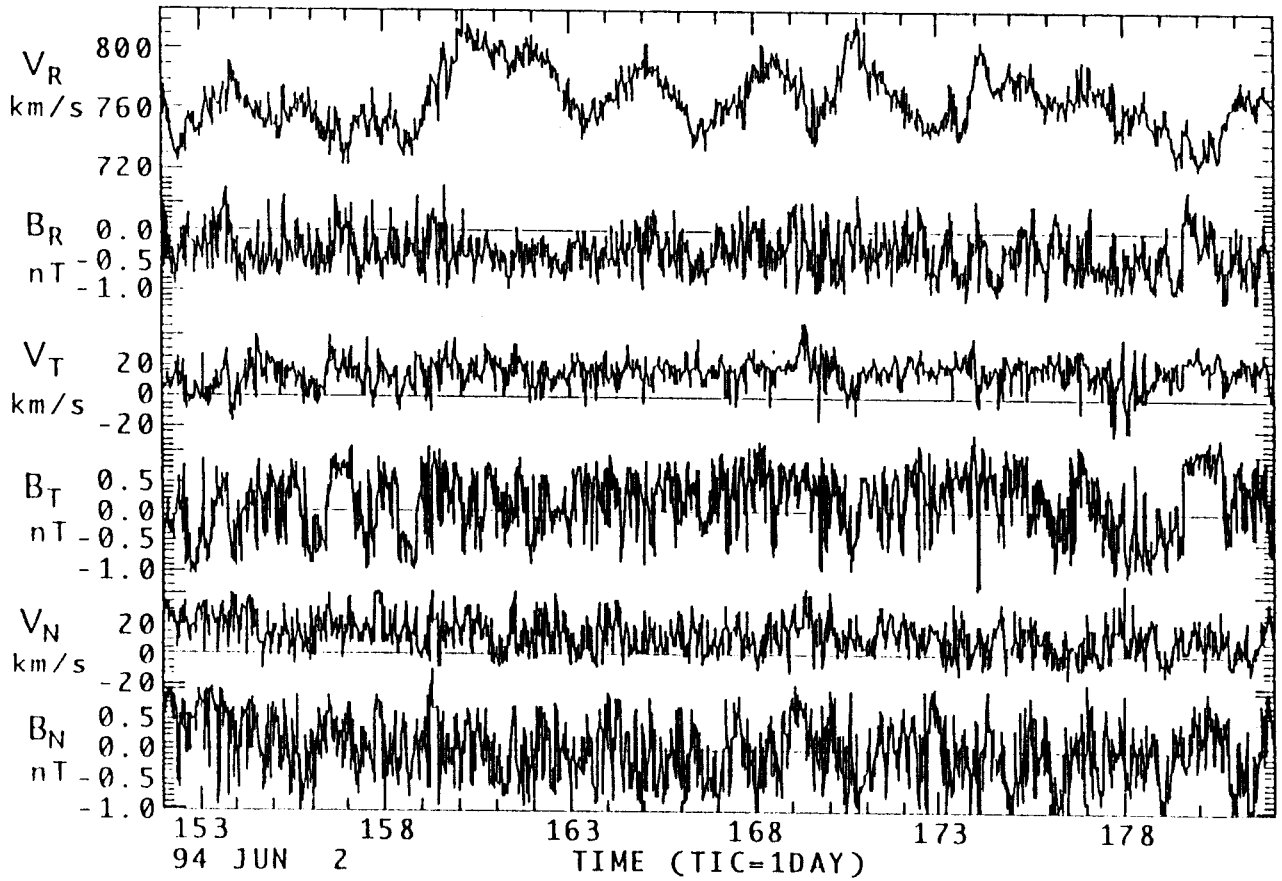


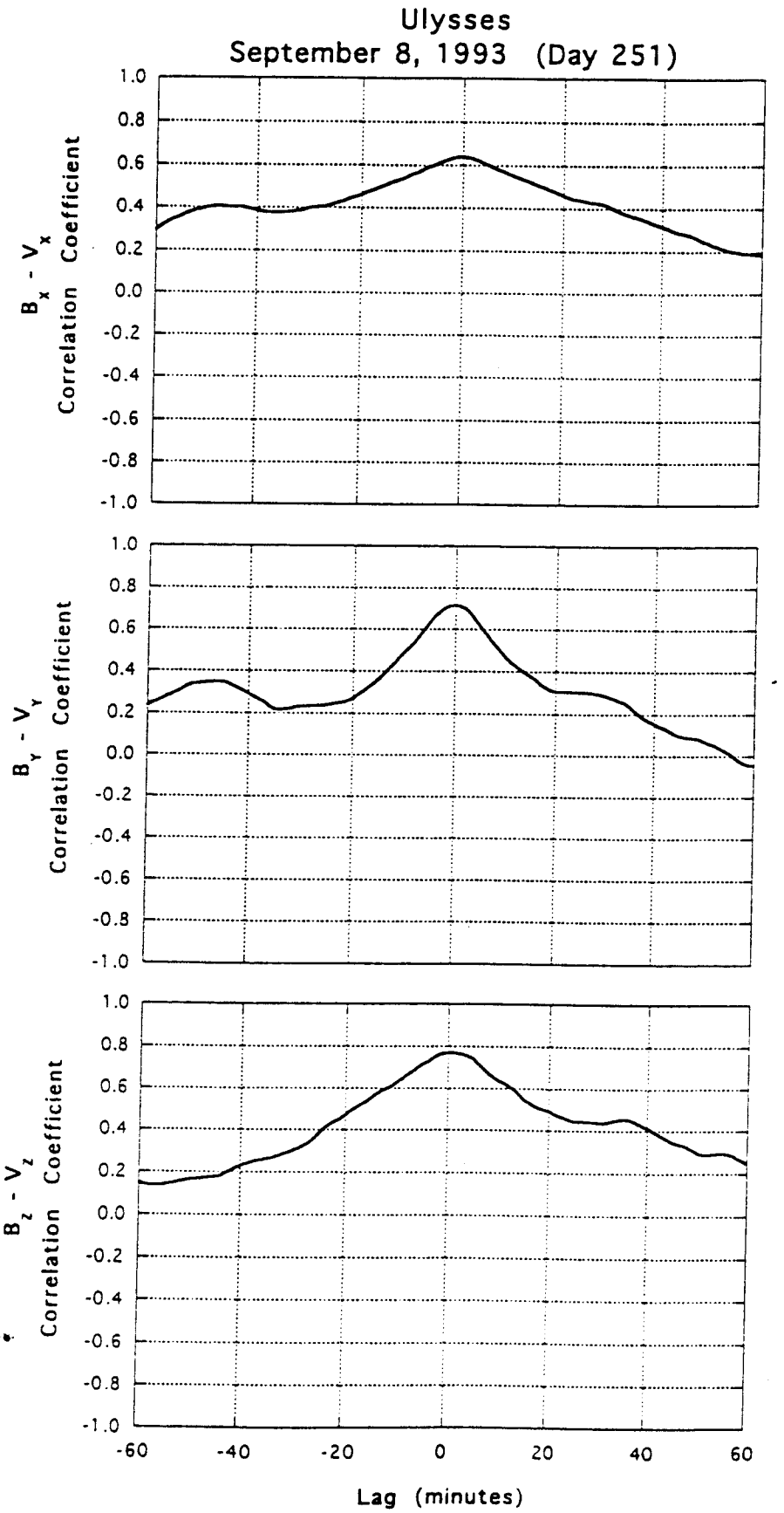

Ulysses South Pole
Days 242-268, 1994
y = 129 e^-4 Δ|B|/B_L
R= 0.96
Δ|B|/B_L ≥ 0.2
Number of Events
60
50
40
30
20
10
0
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Δ|B|/B_L

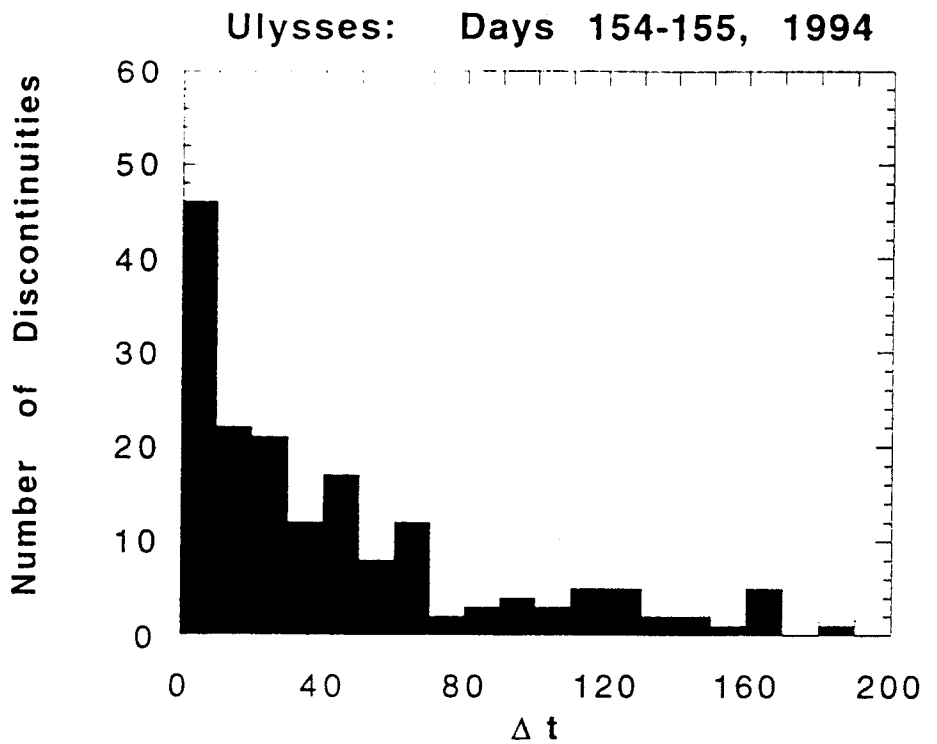

Ulysses South Pole
Days 242-268 1994
Tsurutani-Smith Criteria
(129 discontinuities)
61 %
39 %
Δ|B|/B_L
B_N/B_L
0
0.2
0.4
0.6
0.8
1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

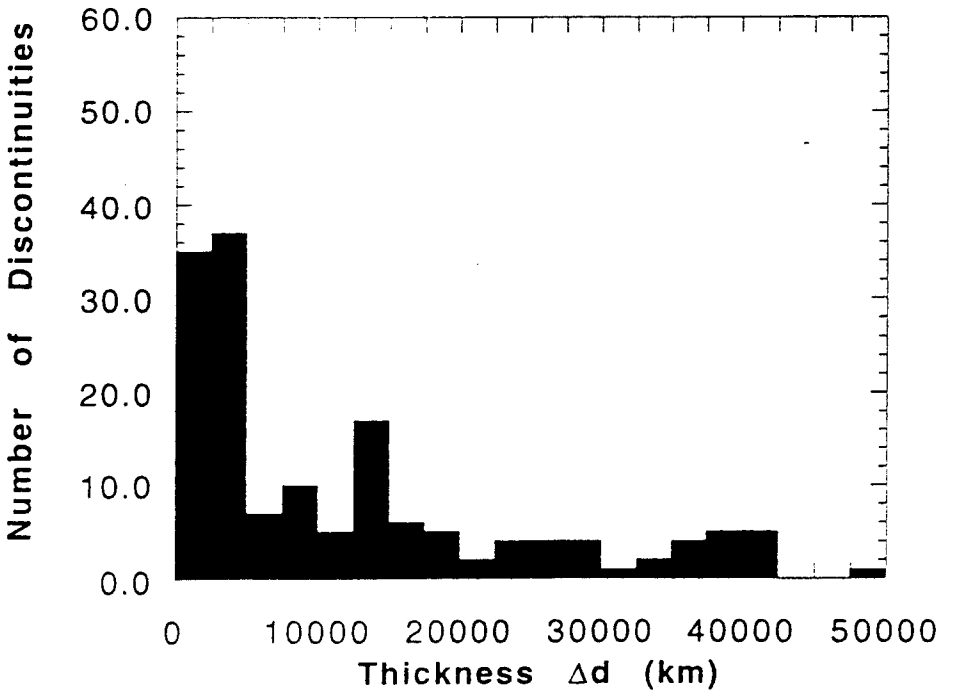


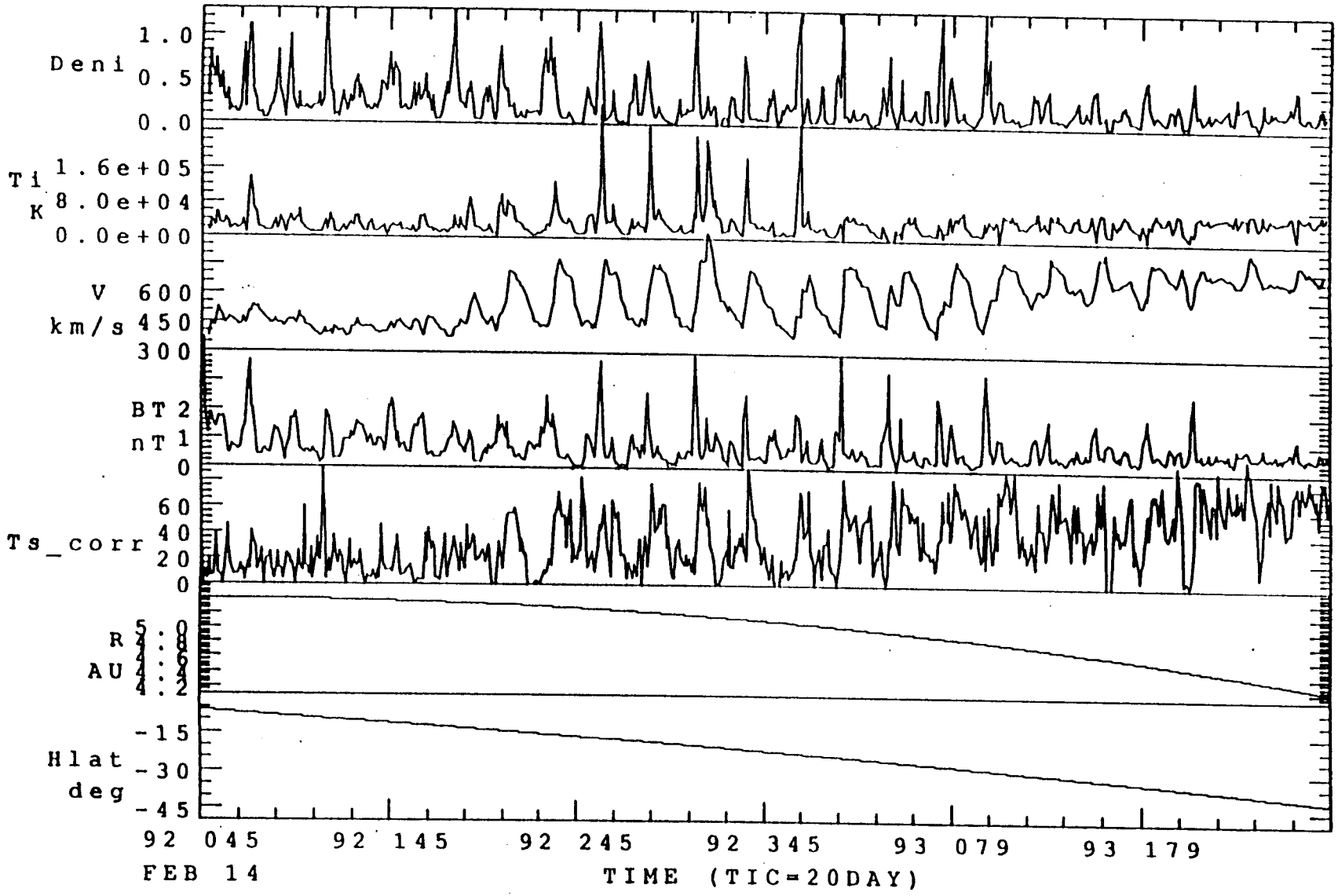
Yohkoh SXT 14 May 1992

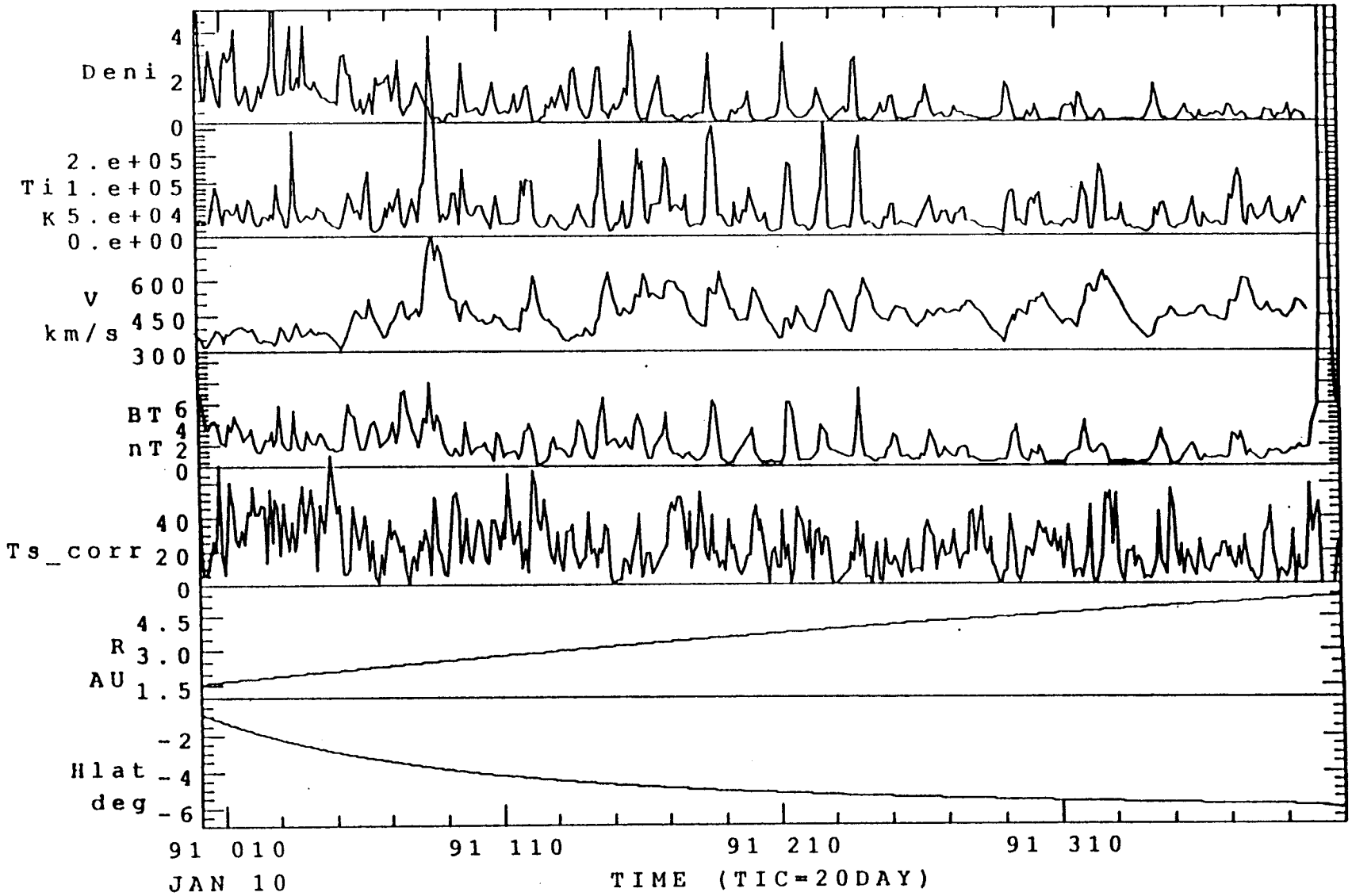

V_R
km/s
800
760
720
B_R
nT
0.0
-0.5
-1.0
V_T
km/s
20
0
-20
B_T
nT
0.5
0.0
-0.5
-1.0
V_N
km/s
20
0
-20
B_N
nT
0.5
0.0
-0.5
-1.0
153
158
163
168
173
178
94 JUN 2
TIME (TIC=1DAY)

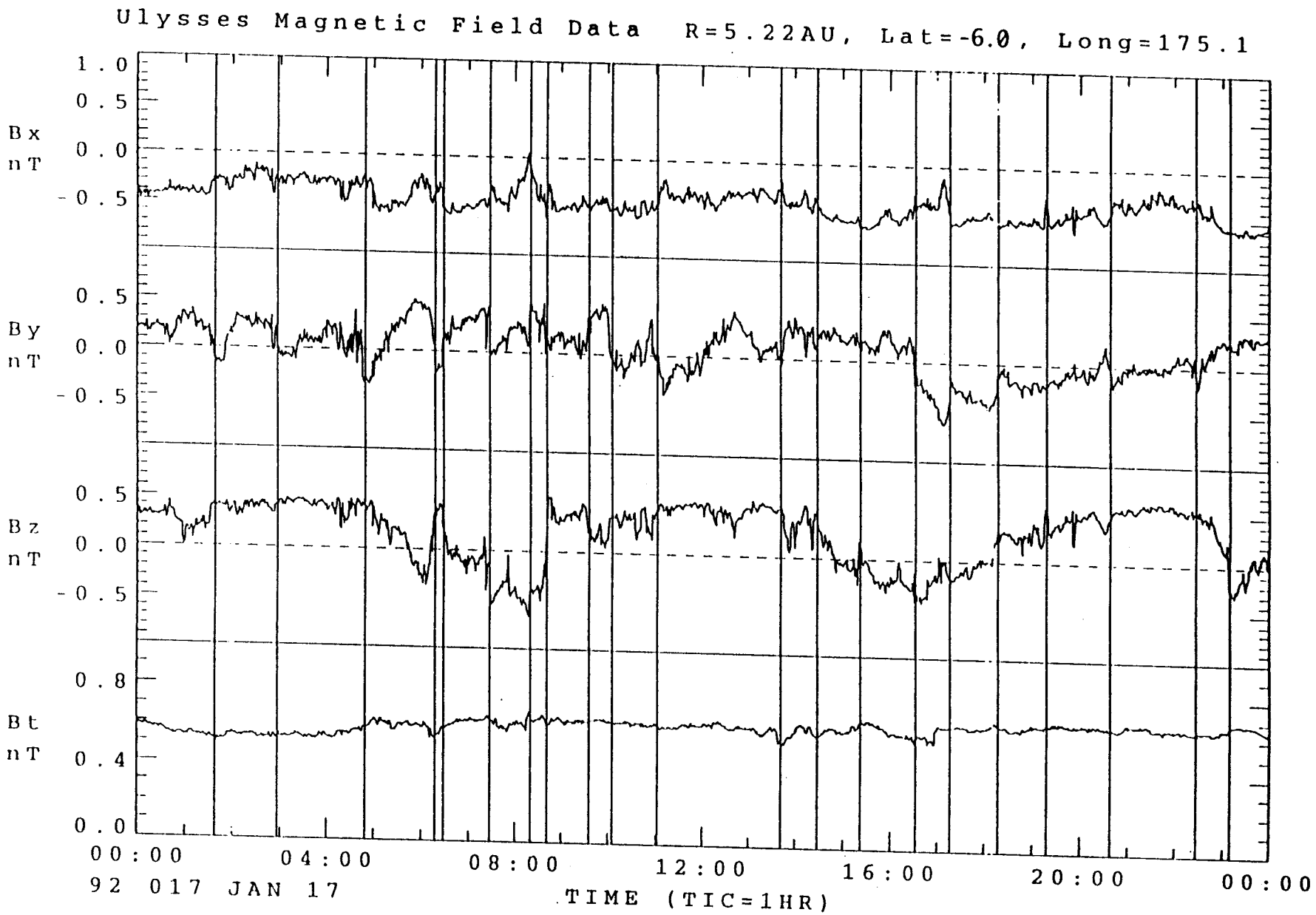

Ulysses
September 8, 1993 (Day 251)
$B_x - V_x$ Correlation Coefficient
$B_Y - V_Y$ Correlation Coefficient
$B_z - V_z$ Correlation Coefficient
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-60
-40
-20
0
20
40
60
Lag (minutes)


Ulysses: Days 154-155, 1994
Number of Discontinuities
60
50
40
30
20
10
0
0
40
80
120
160
200
Δ t


Number of Discontinuities
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
10000
20000
30000
40000
50000
Thickness Δd (km)

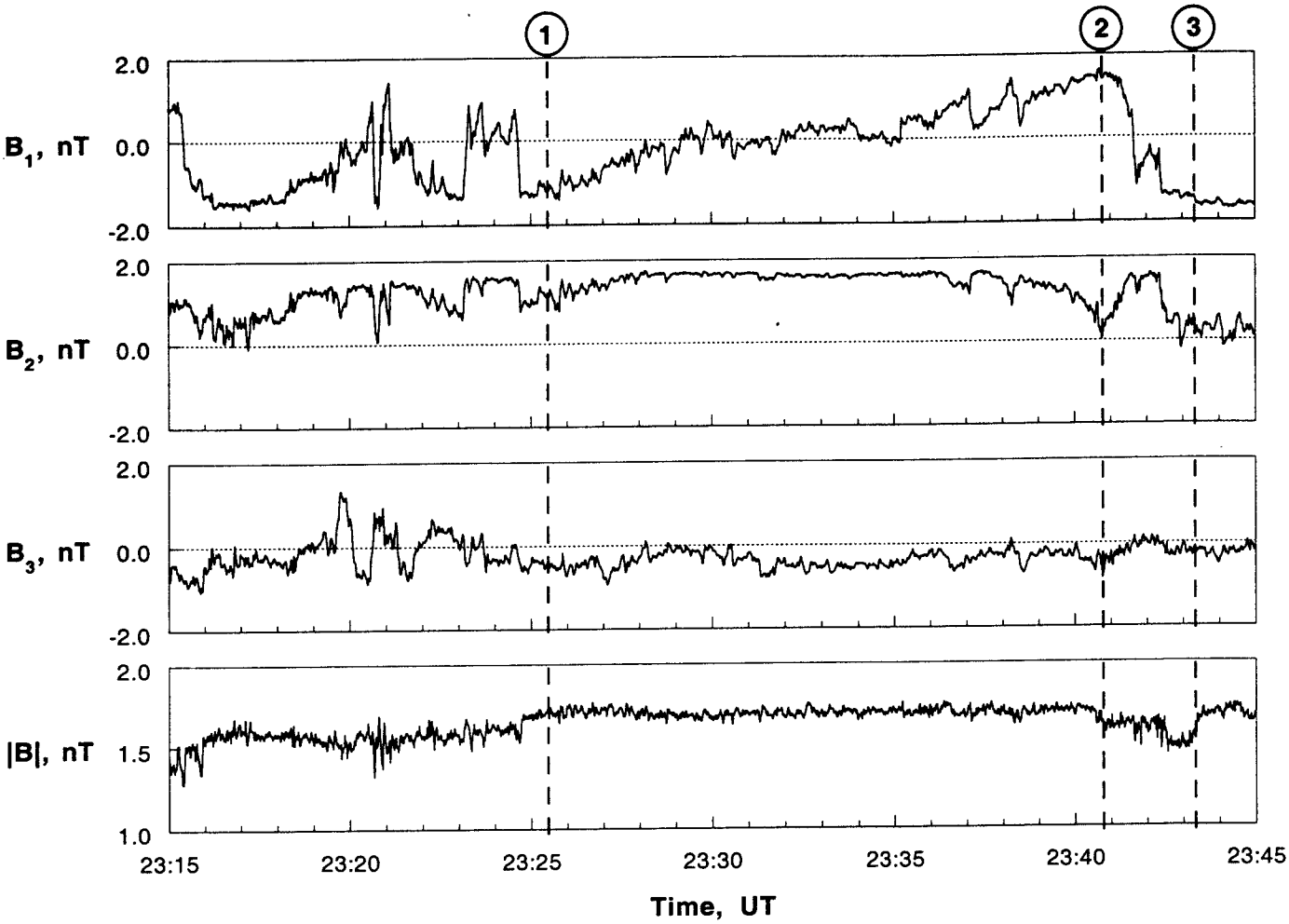

Deni
1.0
0.5
0.0
Ti
K
1.6e+05
8.0e+04
0.0e+00
V
km/s
600
450
300
BT
nT
2
1
0
Ts_corr
60
40
20
0
R
AU
5.0
4.8
4.6
4.4
4.2
Hlat
deg
-15
-30
-45
92 045
FEB 14
92 145
92 245
92 345
93 079
93 179
TIME (TIC=20DAY)


Deni
4
2
0
Ti
2.e+05
1.e+05
5.e+04
0.e+00
V
km/s
600
450
300
BT
nT
6
4
2
0
Ts_corr
40
20
0
R
AU
4.5
3.0
1.5
Hlat
deg
-2
-4
-6
91 010
JAN 10
91 110
91 210
91 310
TIME (TIC=20DAY)

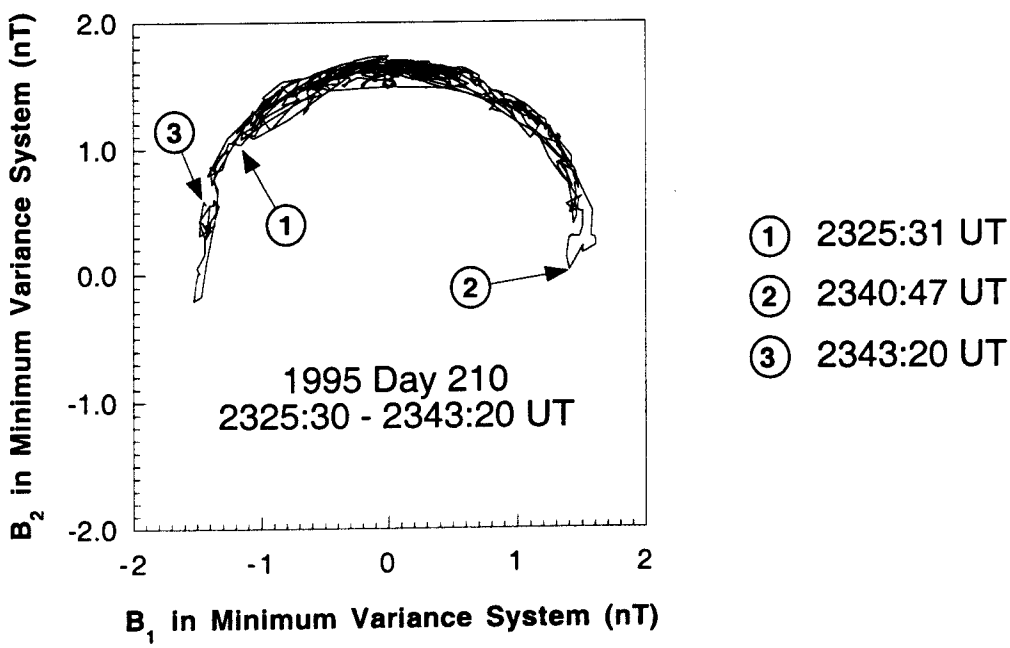

Ulysses Magnetic Field Data R=5.22AU, Lat=-6.0, Long=175.1
Bx
nT
1.0
0.5
0.0
-0.5
By
nT
0.5
0.0
-0.5
Bz
nT
0.5
0.0
-0.5
Bt
nT
0.8
0.4
0.0
00:00
04:00
08:00
12:00
16:00
20:00
00:00
92 017 JAN 17
TIME (TIC=1HR)

Ulysses

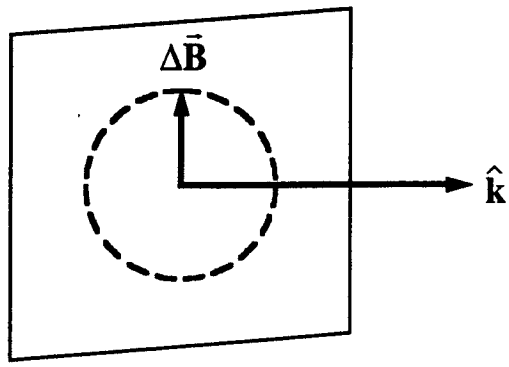
July 29, 1995
Day 210



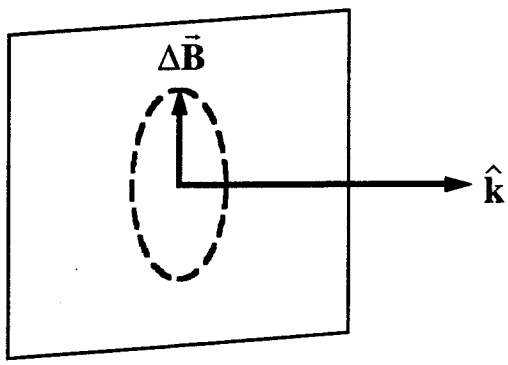
Ulysses Heliographic Latitude = 80.2°



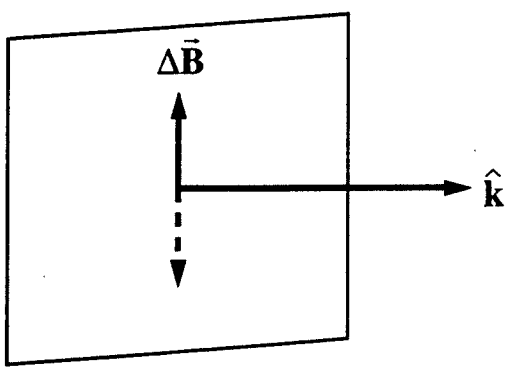
Planar Waves



Circular Polarization

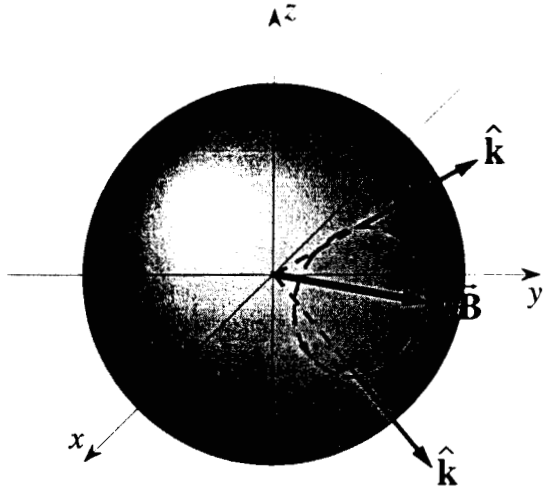


Elliptical Polarization

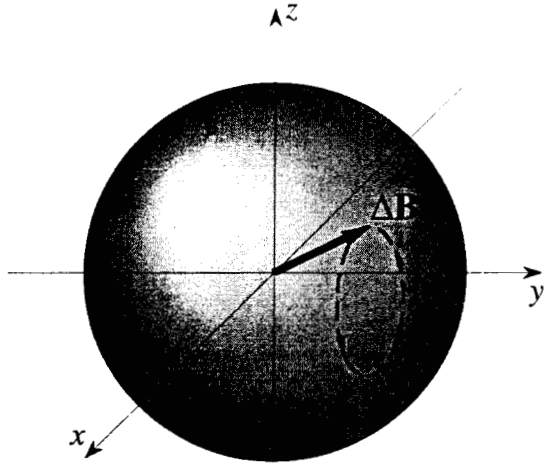


Linear Polarization

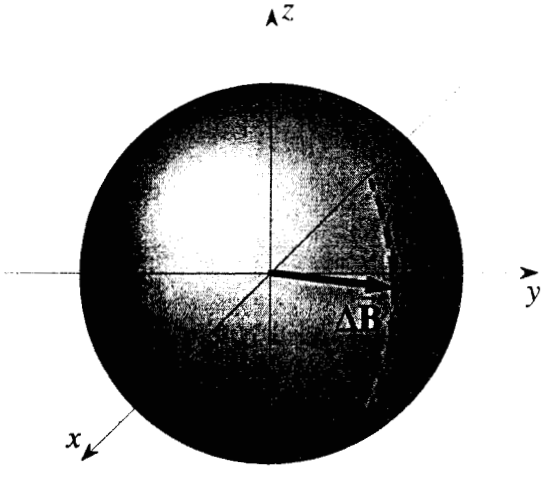
Spherical Waves



Circular Polarization



Elliptical Polarization



Arc Polarization

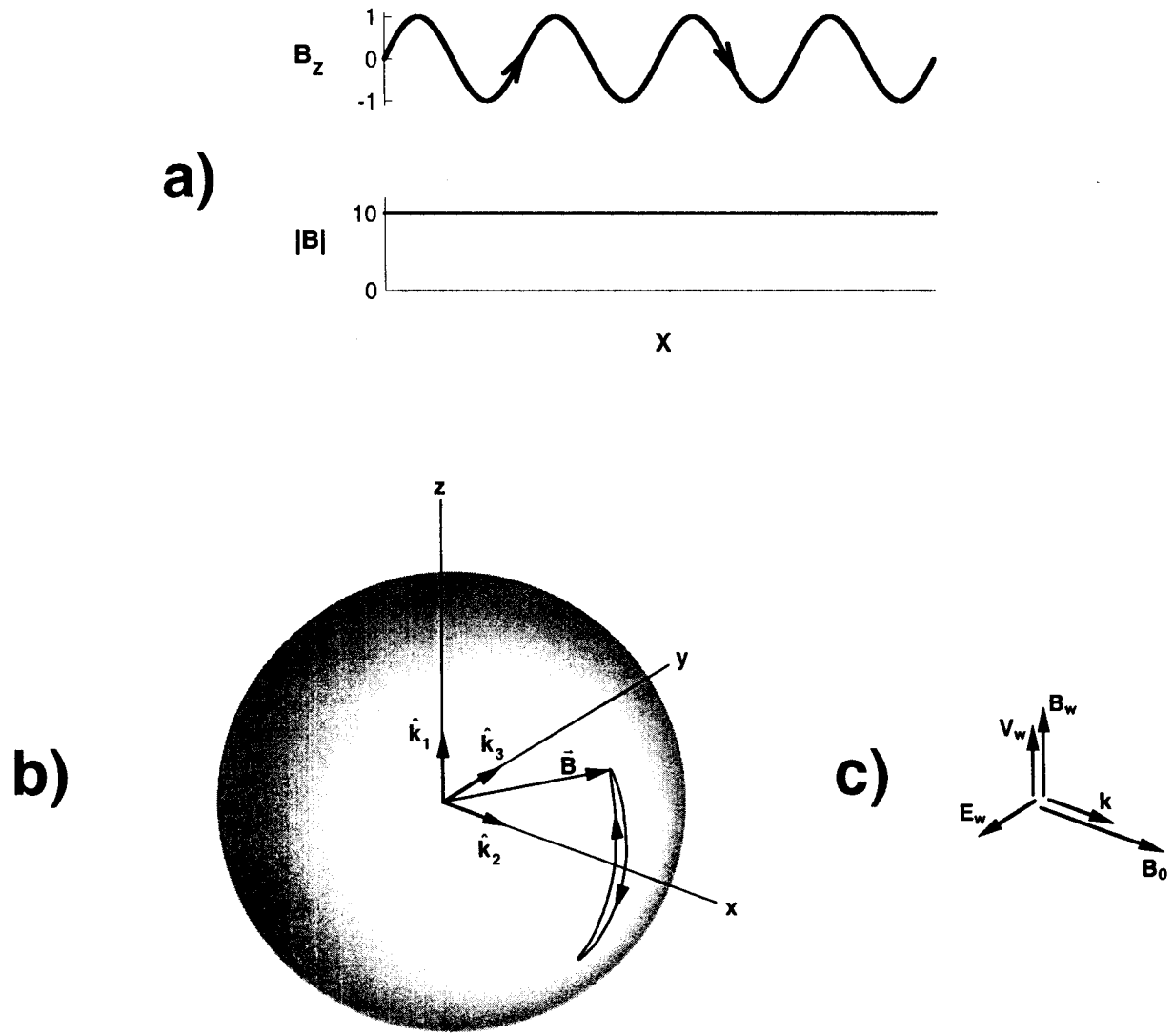
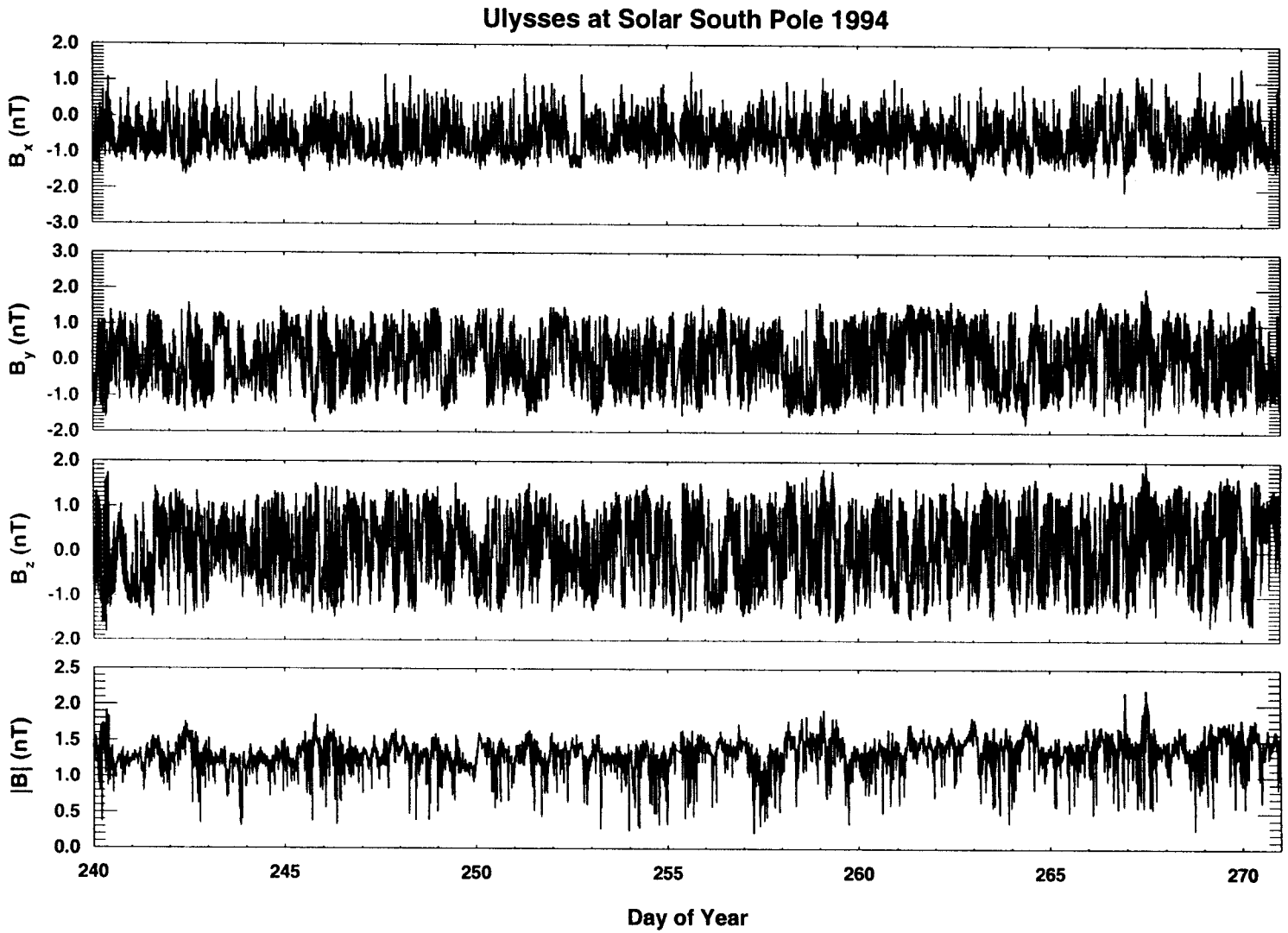
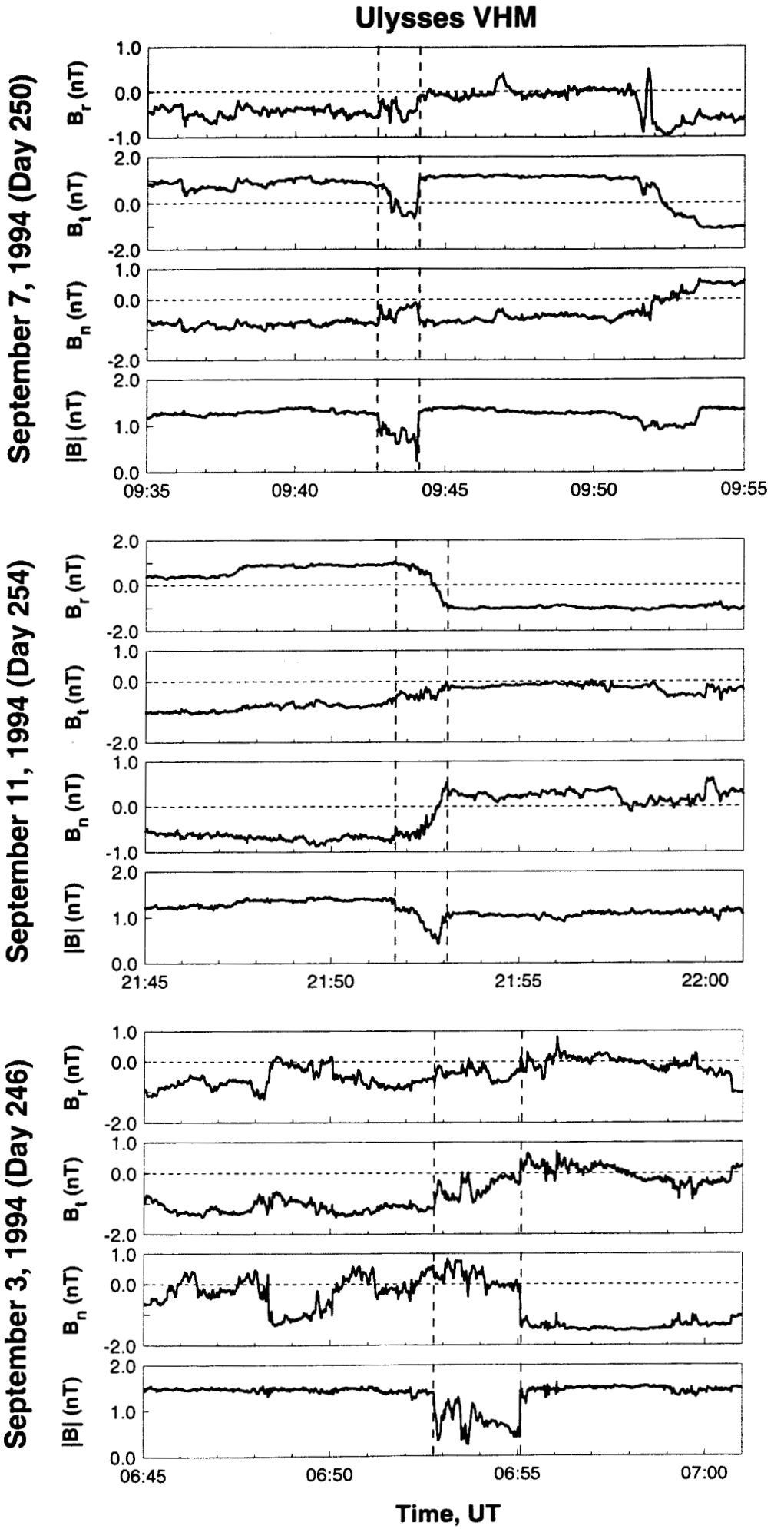
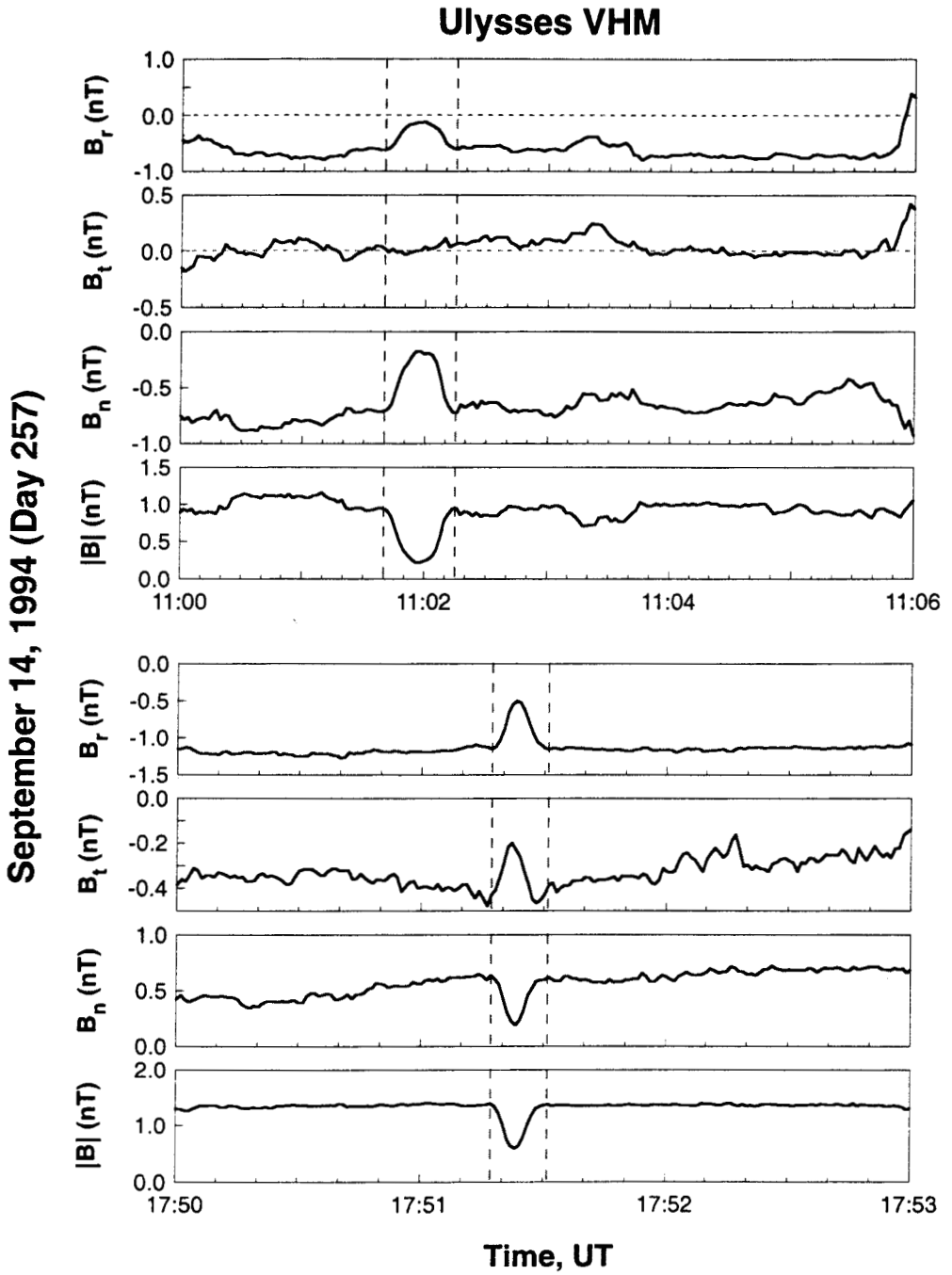


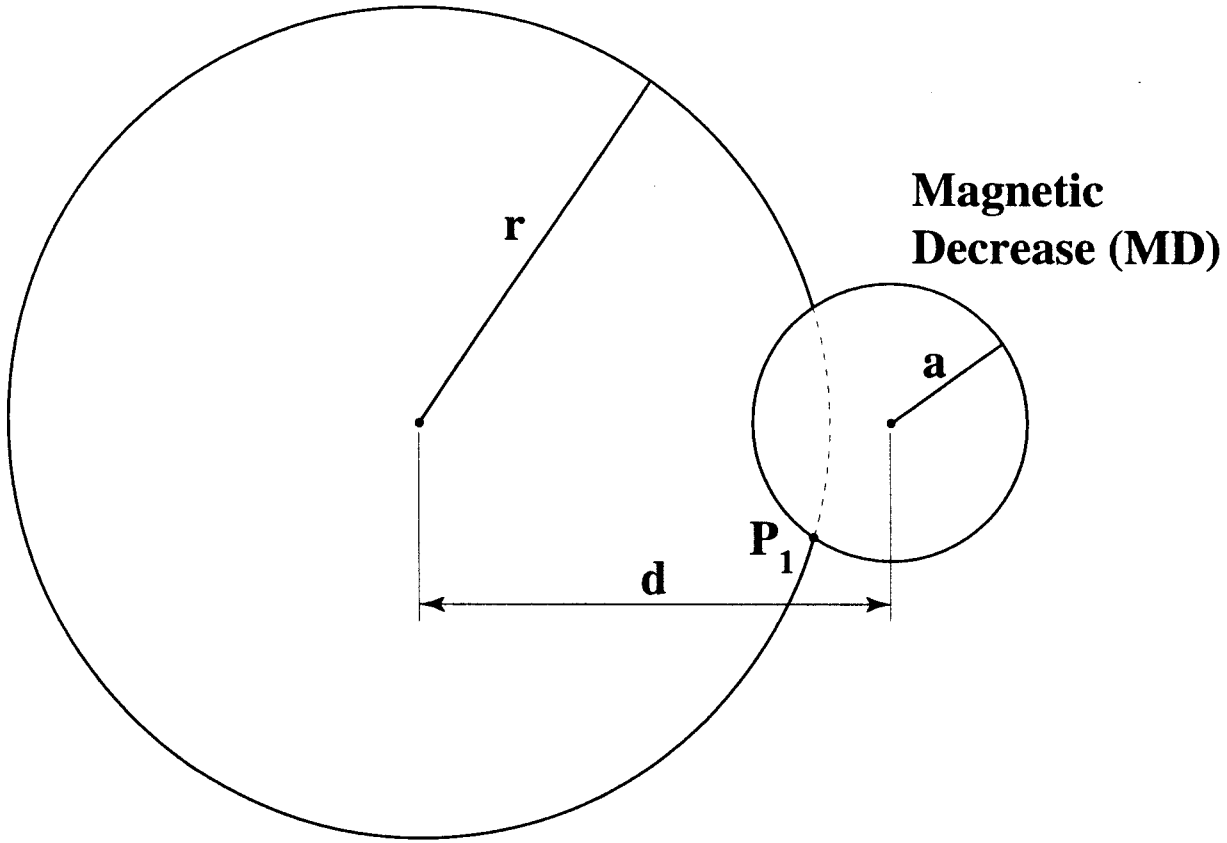
Figure 4


Ulysses at Solar South Pole 1994
B_x (nT)
2.0
1.0
0.0
-1.0
-2.0
-3.0
B_y (nT)
3.0
2.0
1.0
0.0
-1.0
-2.0
B_z (nT)
2.0
1.0
0.0
-1.0
-2.0
|B| (nT)
2.5
2.0
1.5
1.0
0.5
0.0
240
245
250
255
260
265
270
Day of Year

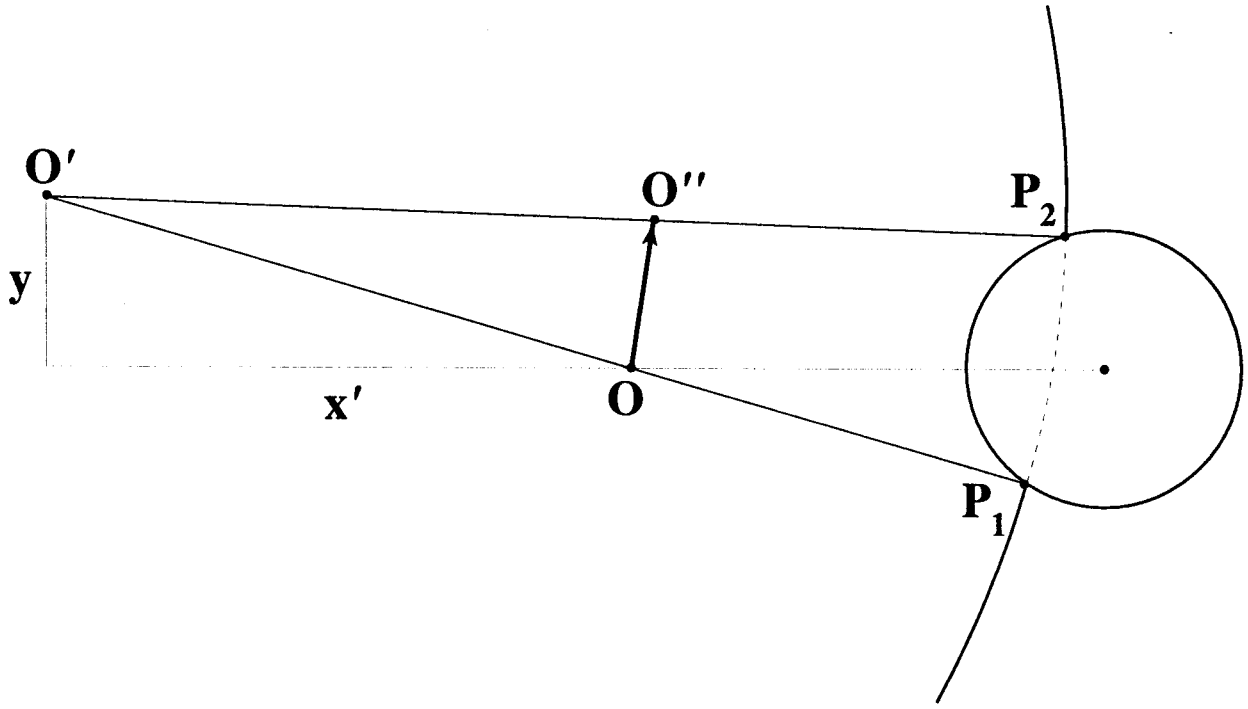

Ulysses VHM
September 7, 1994 (Day 250)
September 11, 1994 (Day 254)
September 3, 1994 (Day 246)
B_r (nT)
B_t (nT)
B_n (nT)
|B| (nT)
09:35
09:40
09:45
09:50
09:55
21:45
21:50
21:55
22:00
06:45
06:50
06:55
07:00
Time, UT


Ulysses VHM
September 14, 1994 (Day 257)
B_r (nT)
B_t (nT)
B_n (nT)
|B| (nT)
1.0
0.0
-1.0
0.5
0.0
-0.5
0.0
-0.5
-1.0
1.5
1.0
0.5
0.0
11:00
11:02
11:04
11:06
B_r (nT)
B_t (nT)
B_n (nT)
|B| (nT)
0.0
-0.5
-1.0
-1.5
0.0
-0.2
-0.4
1.0
0.5
0.0
2.0
1.0
0.0
17:50
17:51
17:52
17:53
Time, UT

Proton Gyromotion

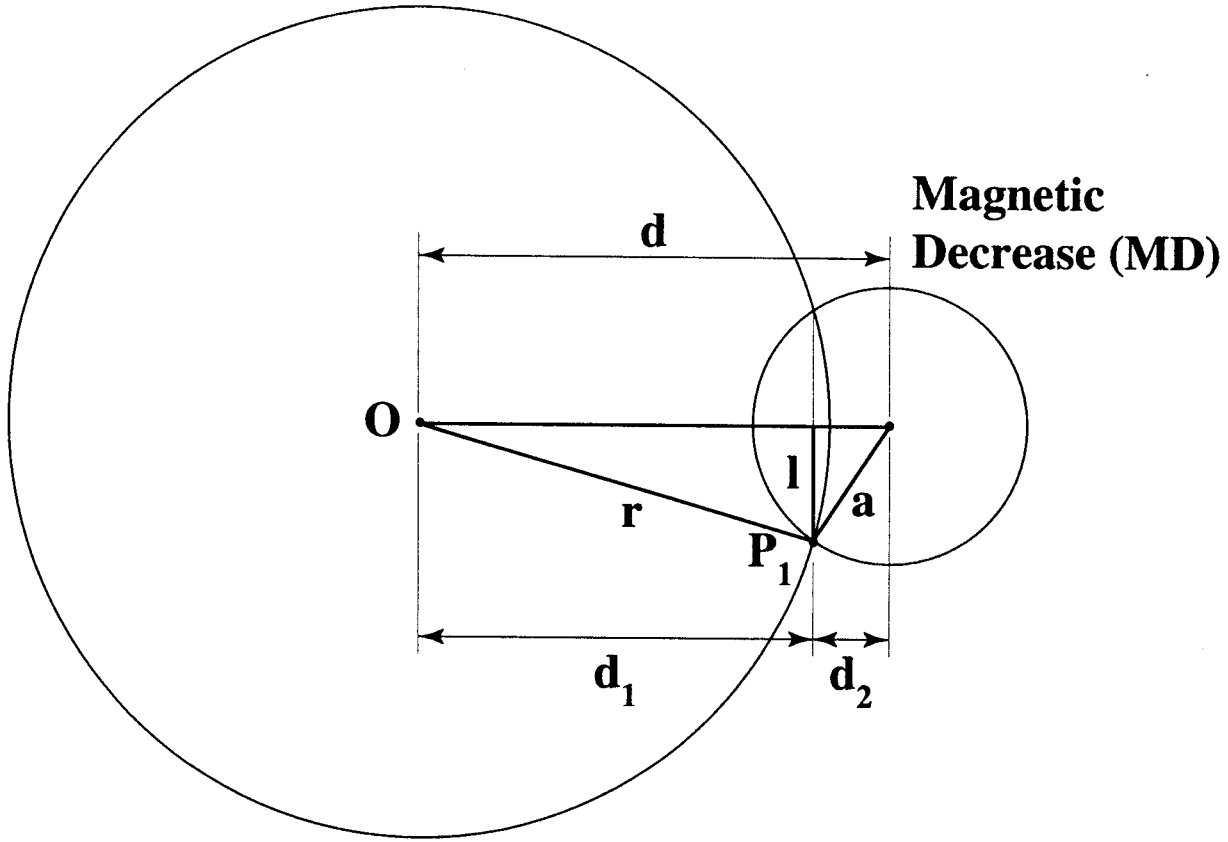


BTT/JKA
July 1999

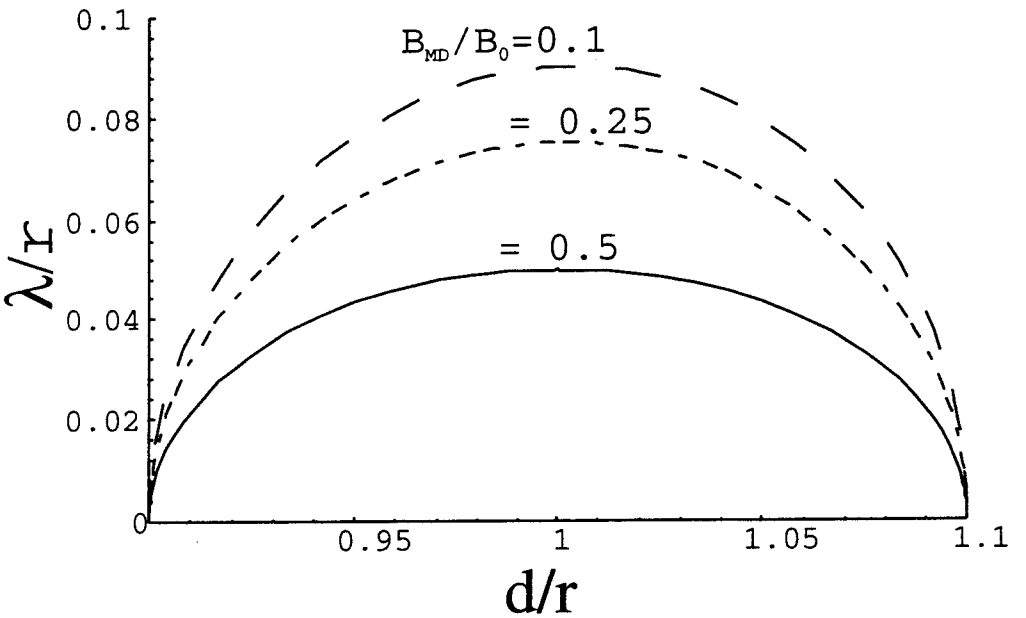


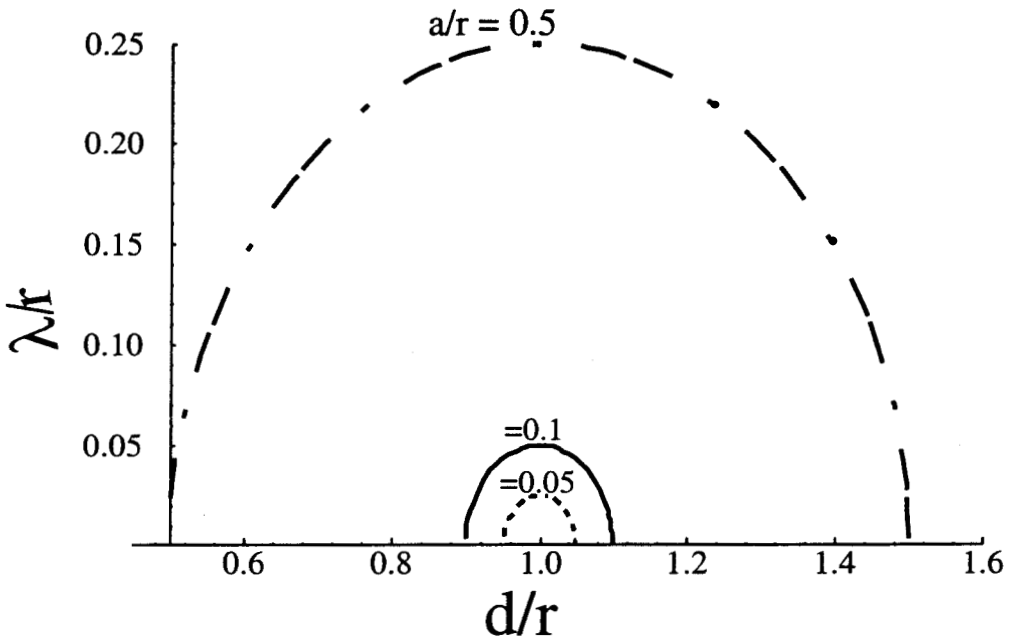
BTT/JKA
July 1999

Proton Gyromotion



BTT/JKA
July 1999


0.1
0.08
0.06
0.04
0.02
0
λ/r
B_MD/B_0=0.1
= 0.25
= 0.5
0.95
1
1.05
1.1
d/r


a/r = 0.5
=0.1
=0.05
0.25
0.20
0.15
0.10
0.05
λ/r
0.6
0.8
1.0
1.2
1.4
1.6
d/r

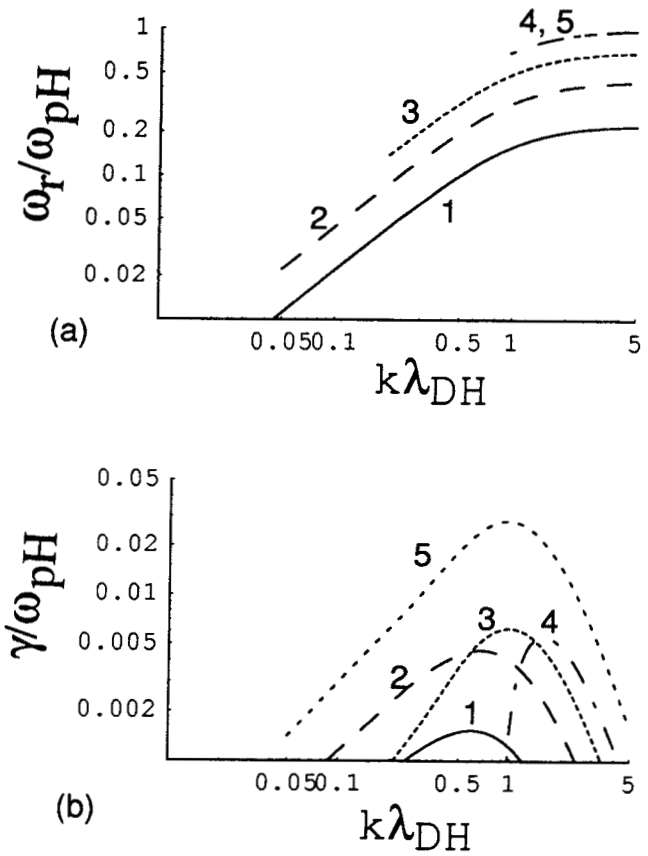

1
0.5
0.2
0.1
0.05
0.02
ω_r/ω_{pH}
4, 5
3
2
1
(a)
0.05 0.1
0.5 1
5
$k\lambda_{DH}$
0.05
0.02
0.01
0.005
0.002
γ/ω_{pH}
5
3
4
2
1
(b)
0.05 0.1
0.5 1
5
$k\lambda_{DH}$

Fig. 3